SIHWA TIDAL – TURBINES AND GENERATORS FOR THE WORLD'S LARGEST TIDAL POWER PLANT

BRITISH HYDROPOWER ASSOCIATION
Bristol, September 18th 2008

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SIHWA TIDAL - Project Highlights

- Largest tidal power plant in the world
- 10 x 26 MW bulb turbine units
- Runner diameter 7.5 m
- Order 2005 - Completion early 2010

SIHWA TIDAL - Project Highlights

PROJECT BACKGROUND:

- **An existing dam built in 1994 (agriculture, reclamation of land)**
- **Industrial and biological pollution → return to natural exchange of water**
- **Korea is investing into renewable energies (Kyoto-Mechanism): from 1.4 % to 5 % in 2011 & reducing oil imports**
- **Total project costs: around 250 million USD**
- **Specific Investment Costs: 250 million USD / 260 MW ≈ 1 million USD / MW**

SIHWA TIDAL – Project Highlights

- **PROJECT STATUS BY GOOGLE EARTH**

SIHWA TIDAL - Client

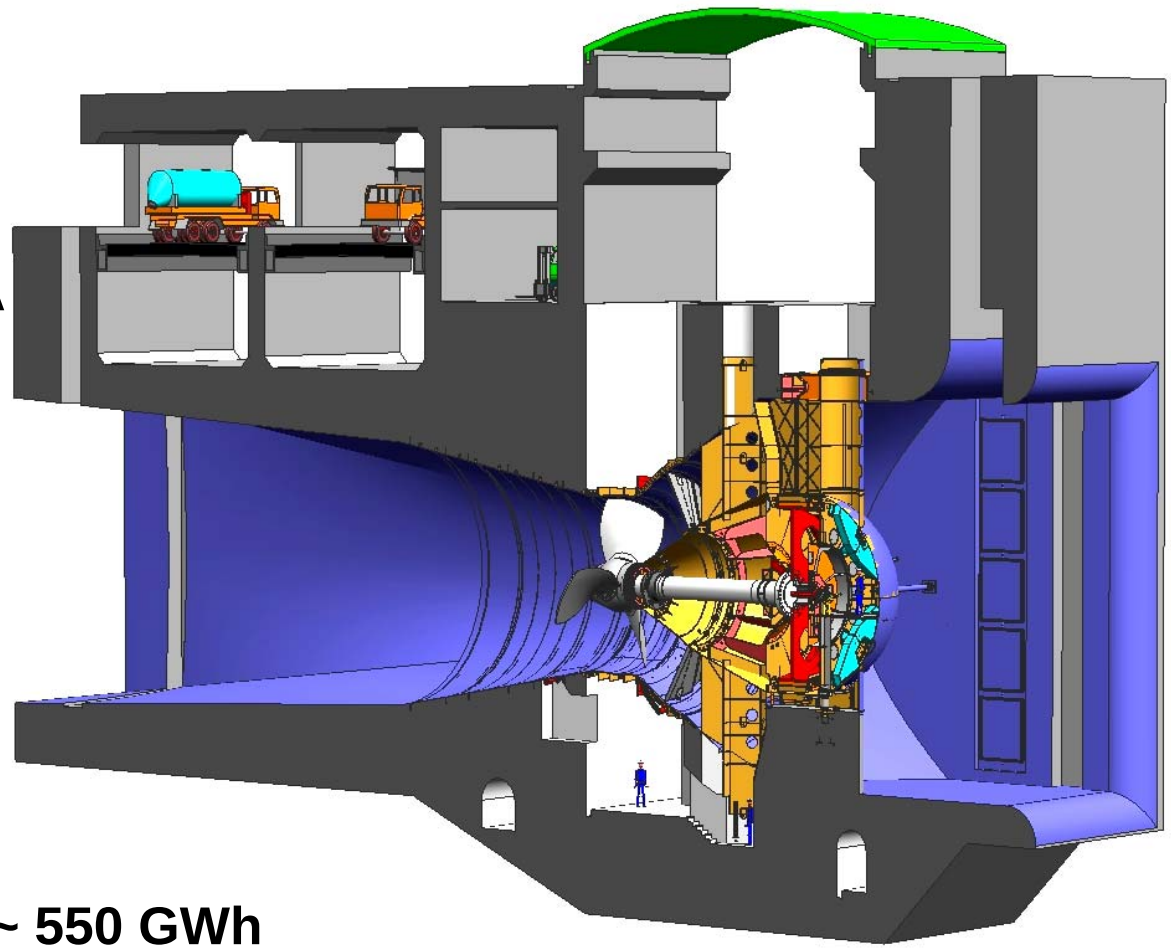
- **K-WATER (Korea Water Resources Corp.) – Project Owner**
  - K-WATER is the governmental water authority of Korea and is the end user of this project. Responsible for irrigation, water supply and waste water
  - Project developer/owner for the Sihwa Tidal Power Project and has strong intention to produce energy beside the necessity of natural exchange of water

- **DAEWOO Engineering & Construction Co, Ltd – Main Contractor**
  - Leading international contractor in the fields of
    - Plant Works (oil & gas, refineries, chemical plants etc.)
    - Civil Works (harbours, dams, roads, bridges, airports, railroads, hospitals, etc.)

- **Andritz VA TECH HYDRO – Technology and EM-Equipment Supplier**

SIHWA TIDAL – Main Technical Data

- 10 Turbine / Generator units
- Runner diameter 7.5 m
- Turbine Output 26 MW
- Generator Output 26.8 MVA
- Rated speed 64.3 rpm
- Rated head 5.82 m
- Rated discharge 482.1 m^3/s
- Rated voltage 10.2 kV
- Rated current 1515 A
- Annual energy production ~ 550 GWh



SIHWA TIDAL – Tidal Power Plants

HISTORY AND SITES

- Tidal mills in the 18th century
- Invention of tidal power plants in the early 1900's
- Rather few tidal plants have been built …
- Two large ones: La Rance (FRA), Annapolis (CAN)
- Some other sites in China and Russia below 5 MW

SIHWA TIDAL – Tidal Power Plants

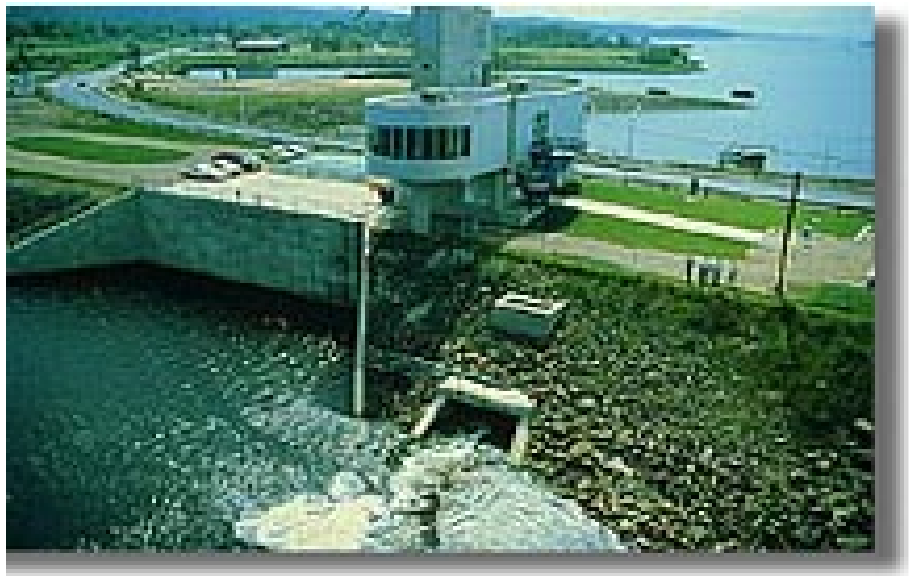
LA RANCE, FRANCE

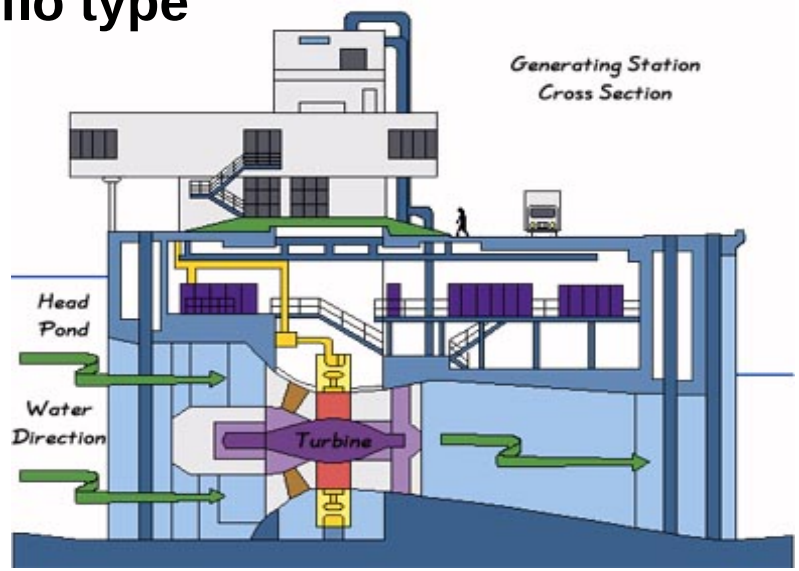
- 24 x 10 MW
- Runner diameter 5,35 m
- Built 1961 - 1967
- Multiple mode operation
- Pump-turbines for both flow directions
- Successful operation since 40 years !
- Basin area 22 km²

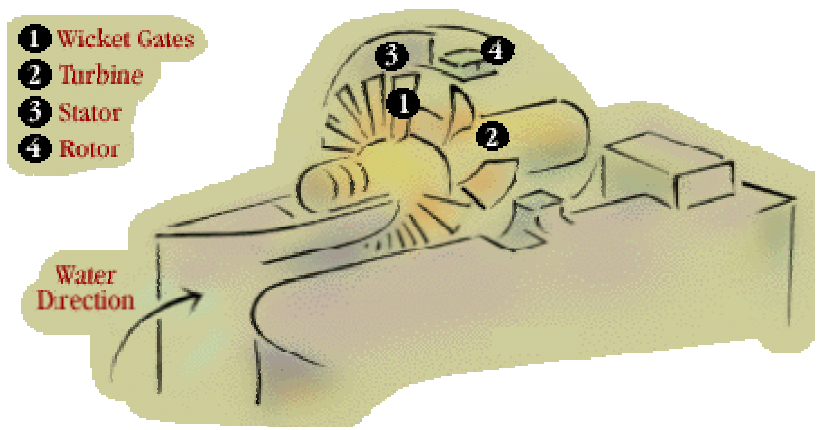
SIHWA TIDAL – Tidal Power Plants

ANNAPOLIS, CANADA

- 1 x 18 MW
- Runner diameter 7,8 m
- Commissioned in 1984
- Single operation mode
- Straflo type



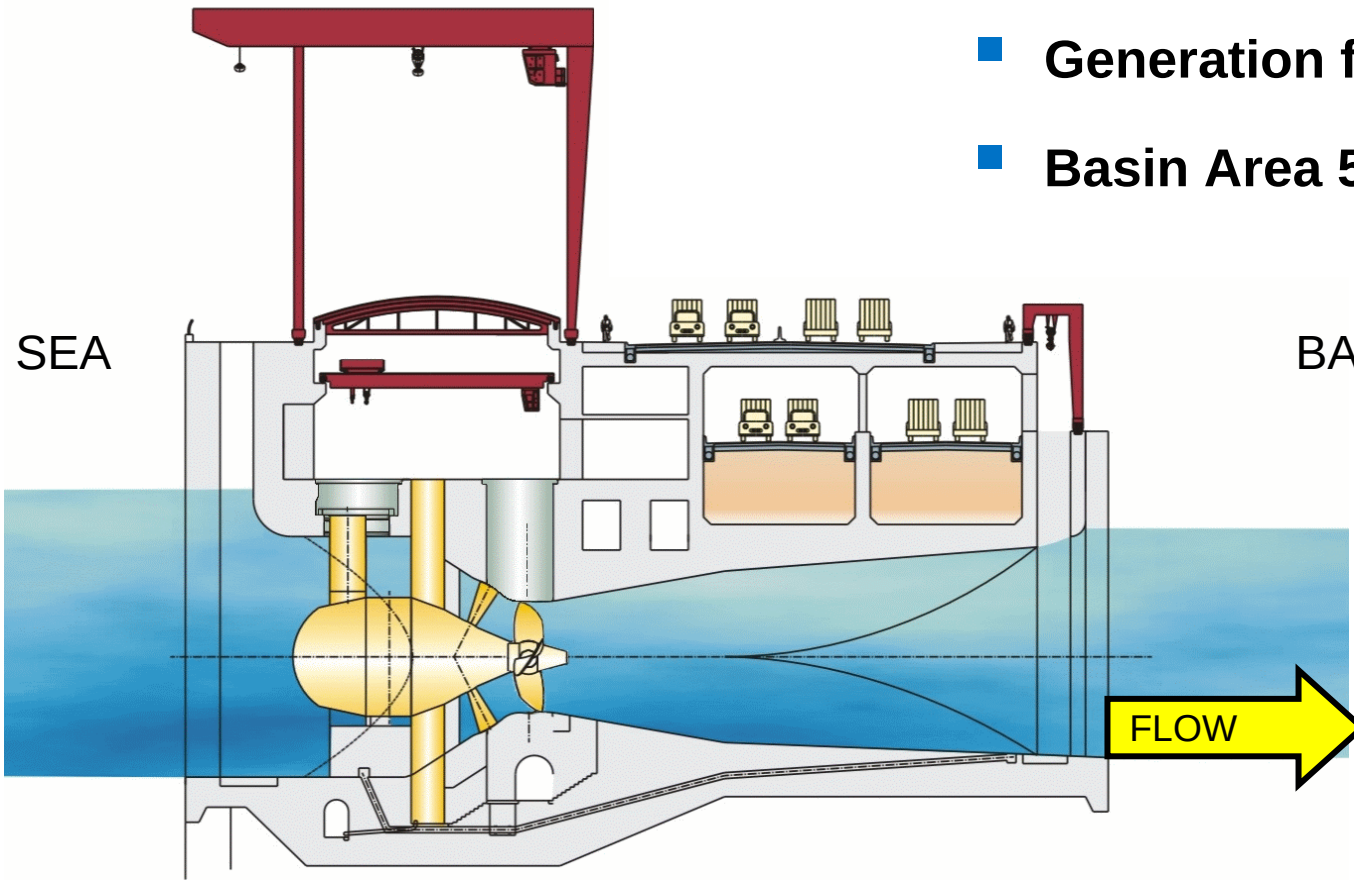




SIHWA TIDAL – Tidal Power Plants

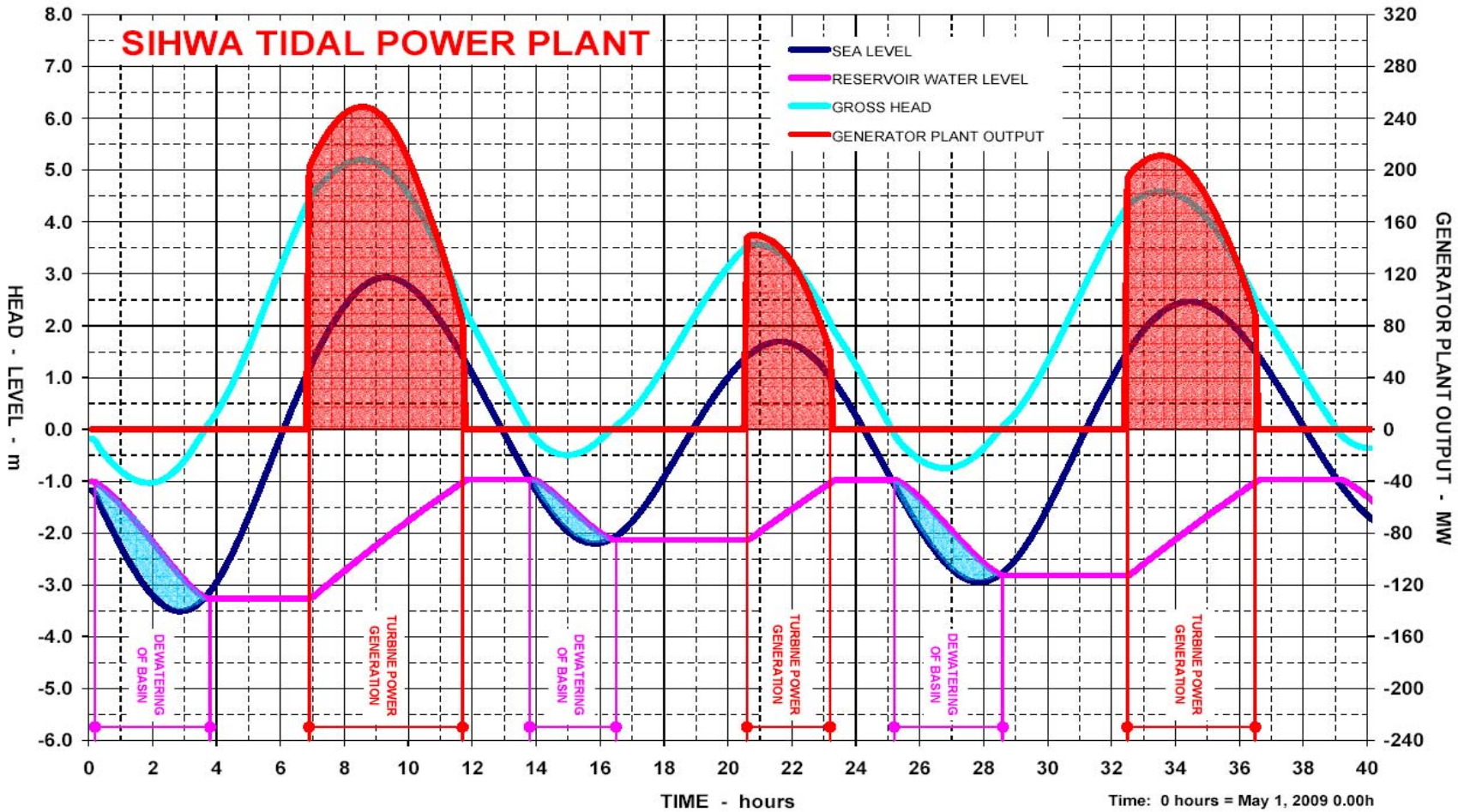
SIHWA, SOUTH KOREA

- **Single direction units**
- **Generation from sea to basin**
- **Basin Area 56 km²**



SIHWA TIDAL – Plant Operation

OPERATION OF SIHWA TIDAL POWER PLANT



SIHWA TIDAL – Technical Issues

Significant Differences of River Run to Tidal Power Bulb Turbines

- Corrosion Protection
- Reverse Mode Operation (Sluicing)
- High Number of Start and Stops
- Permanent Governing due to Changes of the Head
- Earthquakes

Corrosion Protection

- **Cathodic Protection System**

  with this system the potential of the protected components is made more negative to avoid the dissolution (corrosion) of metal.

  The necessary protective current depends on oxygen content of sea water, salt content, alkalinisation of protected surfaces, temperature, flow velocity.

- **Special precaution** to areas which cannot be protected by cathodic protection system:
  - sea water resistant stainless steel material
  - overlay welding with sea water resistant electrodes
  - tight welding seam of flange connections
  - sacrificial anodes

SIHWA TIDAL – Technical Issues

Corrosion Protection

Material Selection

For components like runner blades, runner hub, special steel with higher grade of chromium and molybdenum have been chosen

Components usually made of carbon steel like runner cone, gate barrel cones, wicket gates, water passage shield are made of stainless steel

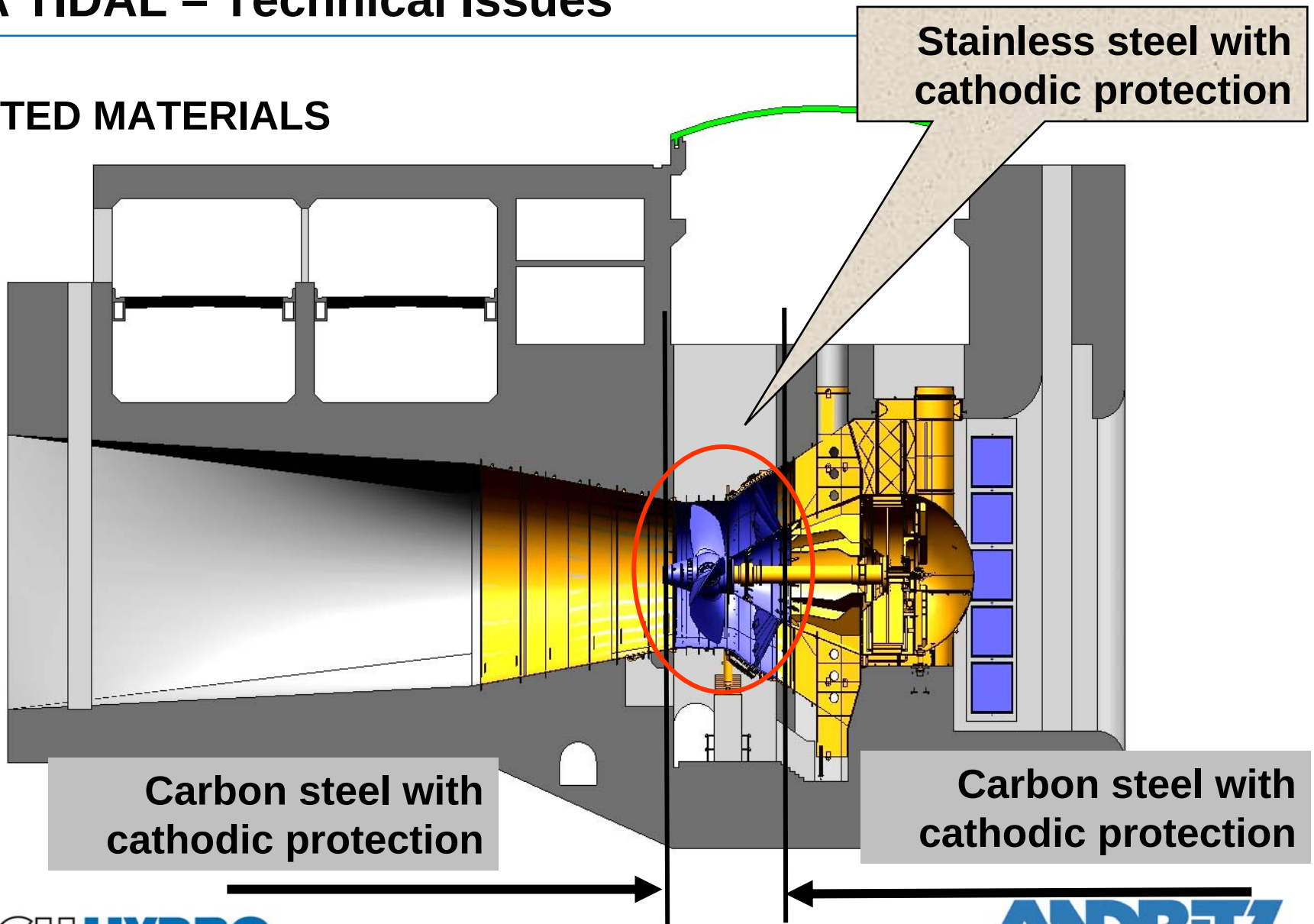
Coolers are stainless steel plated

Painting

Painting material resistant to sea water and reliable for cathodic protection system will be used for all sea water contacted surfaces of carbon steel components.

SIHWA TIDAL – Technical Issues

SELECTED MATERIALS



Reverse Mode Operation (Sluicing)

- Because of the limitation of the maximum lake level (-1.0 Meter) and economic considerations, the units generate power only in direction from sea to lake.
- For releasing of water from the lake during the ebb. 6 existing and 8 newly installed gates will be opened and the turbines are operating in reverse direction without producing power.
- Counterthrust to thrust bearing has to be considered in the design.
- The assure low vibration during this operation the correlation of runner blade and wicket gate position was tested during model test.

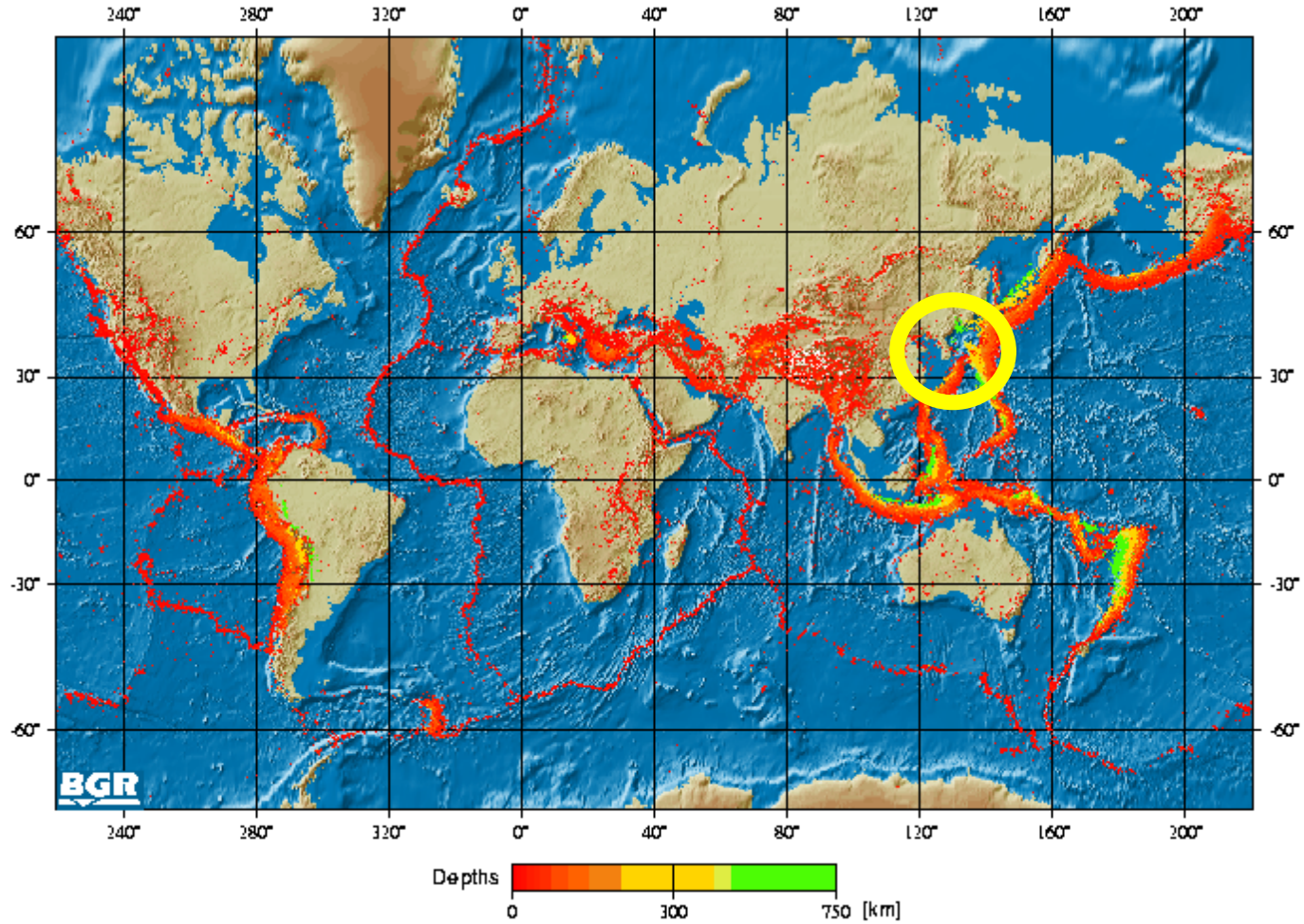
SIHWA TIDAL – Technical Issues

High Number of Starts and Stops

- The units have are put in operation two times per day.
- The units are also in operation two times per day in reverse mode.
- Compared with a run river of river bulb turbine unit the number of starts and stops is much higher and it has to be considered in the design and calculation of the equipment (no constant operating temperature, condensation).
- Detailed structural and electromagnetic calculations had to be carried out to insure proper functioning of generator under “unsteady thermal behavior”.

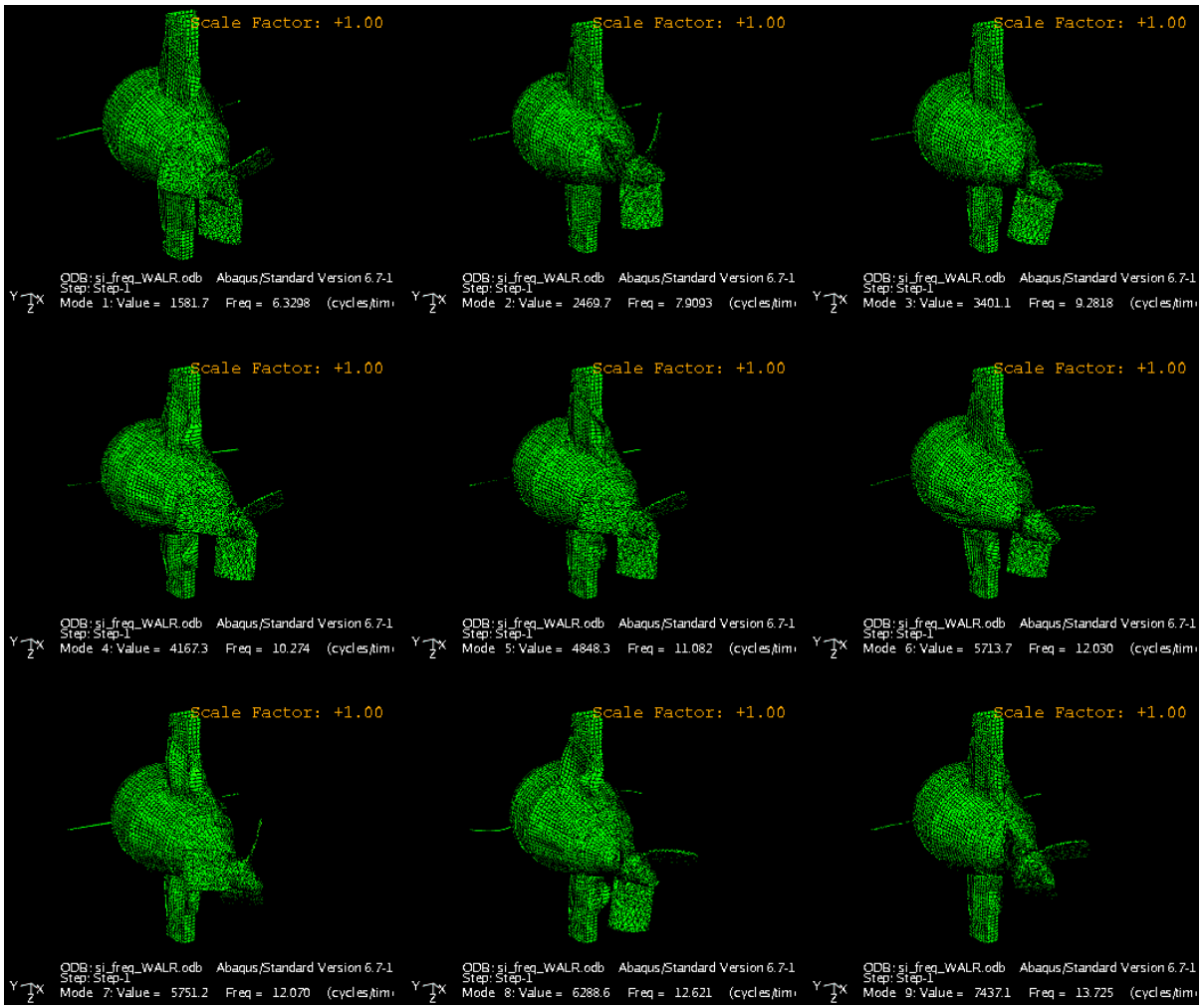
SIHWA TIDAL – Technical Issues

Earthquakes worldwide 1954-2003

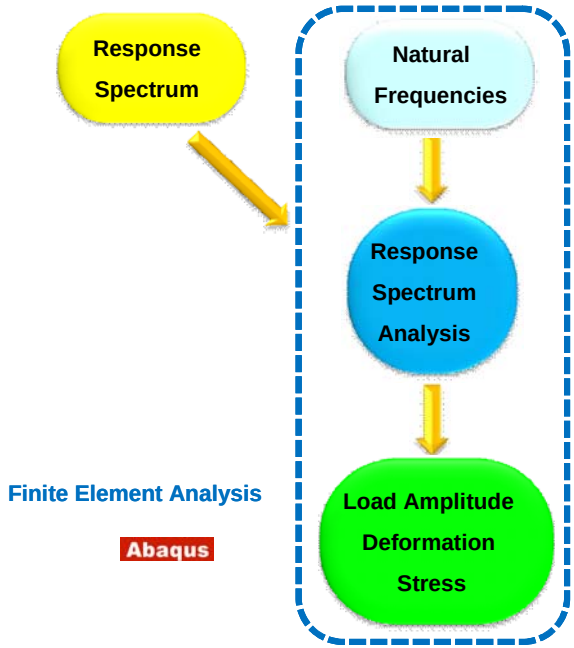


Orig.: SDAC, Hannover

SIHWA TIDAL – Technical Issues

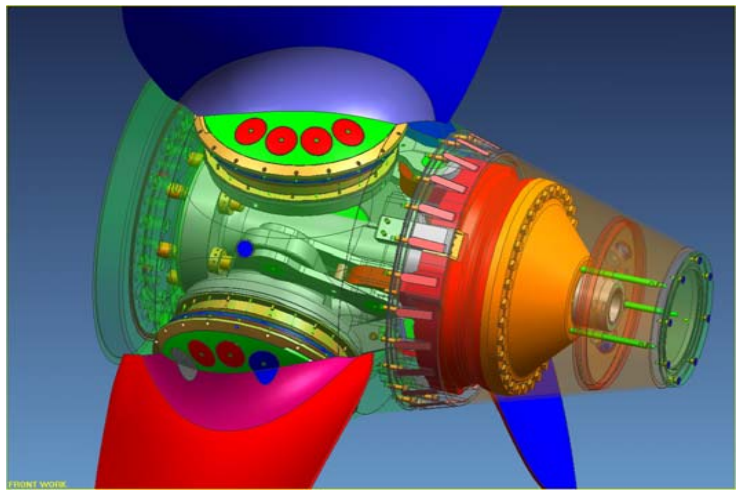


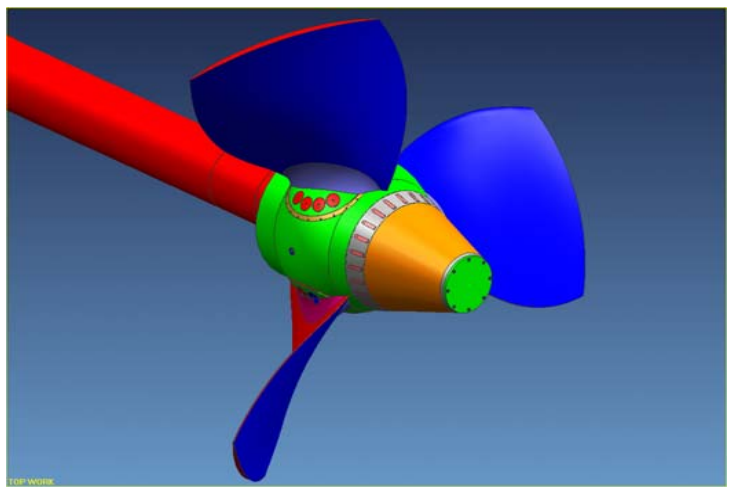
- **Modal Analysis**
- **Extraction of natural frequencies**



SIHWA TIDAL - Manufacturing

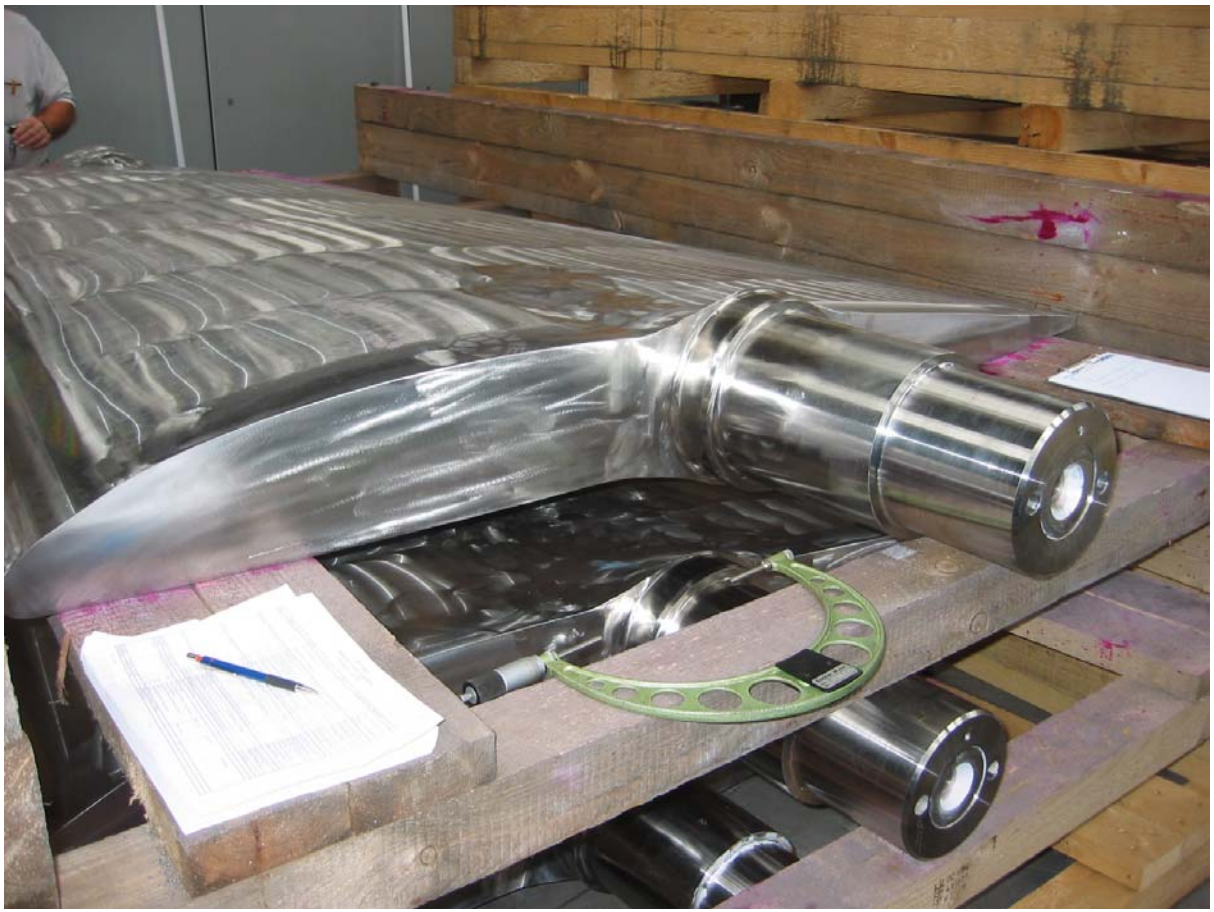
- **Turbine Runner**

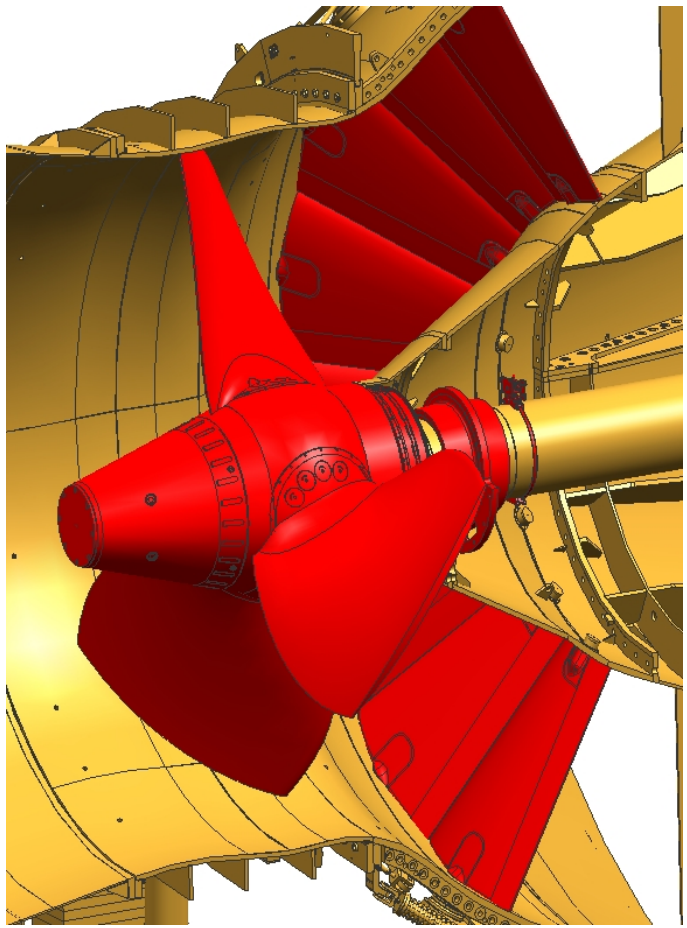




SIHWA TIDAL - Manufacturing

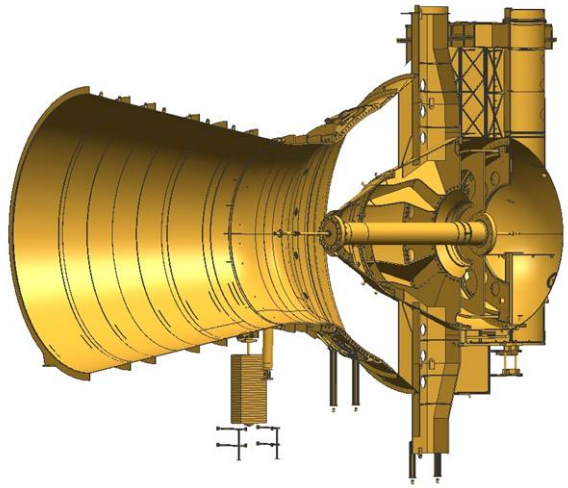
- **Wicket Gates**

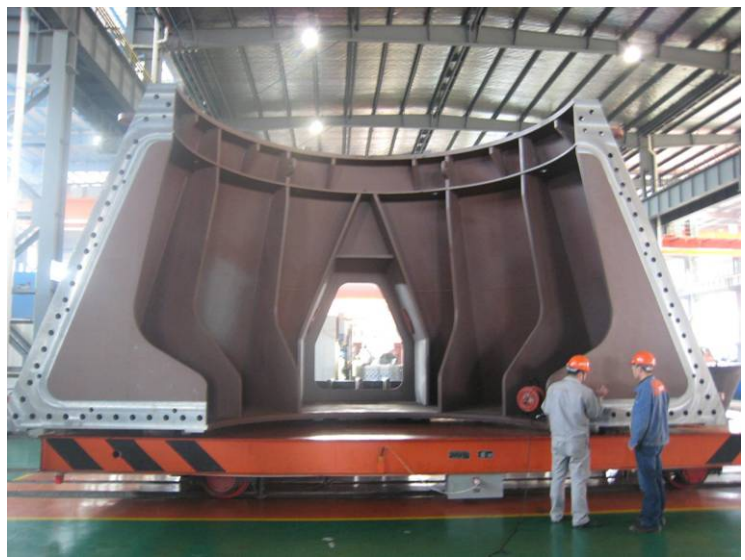




SIHWA TIDAL - Manufacturing

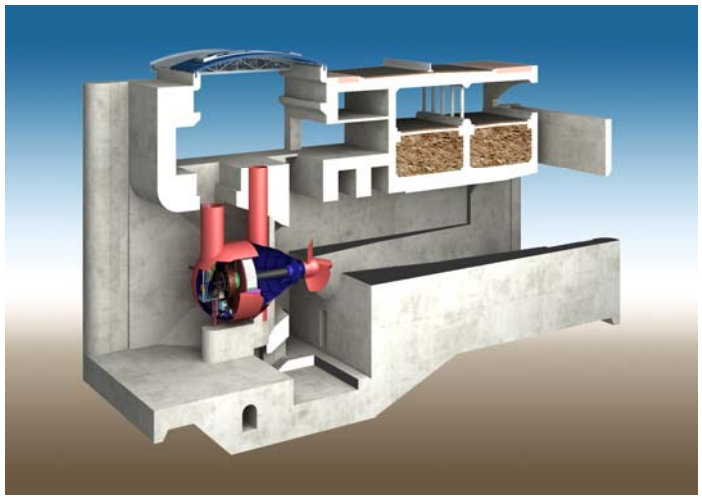
- **Bulb Case**

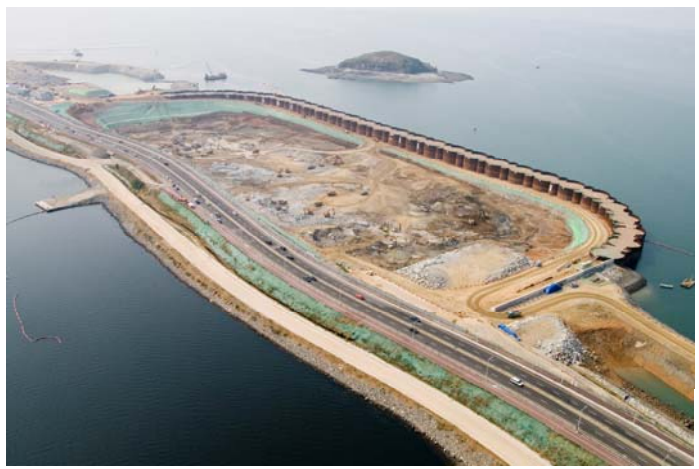




SIHWA TIDAL – Site Installation

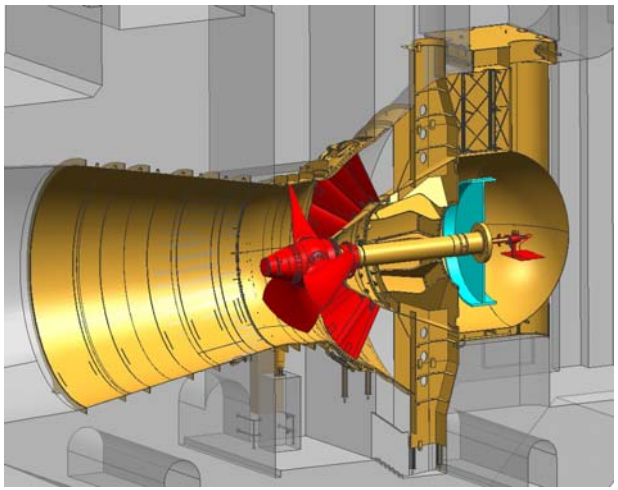
- **Powerhouse Construction**





SIHWA TIDAL – Site Installation

- **Draft tube installation**



SIHWA TIDAL – Site Installation

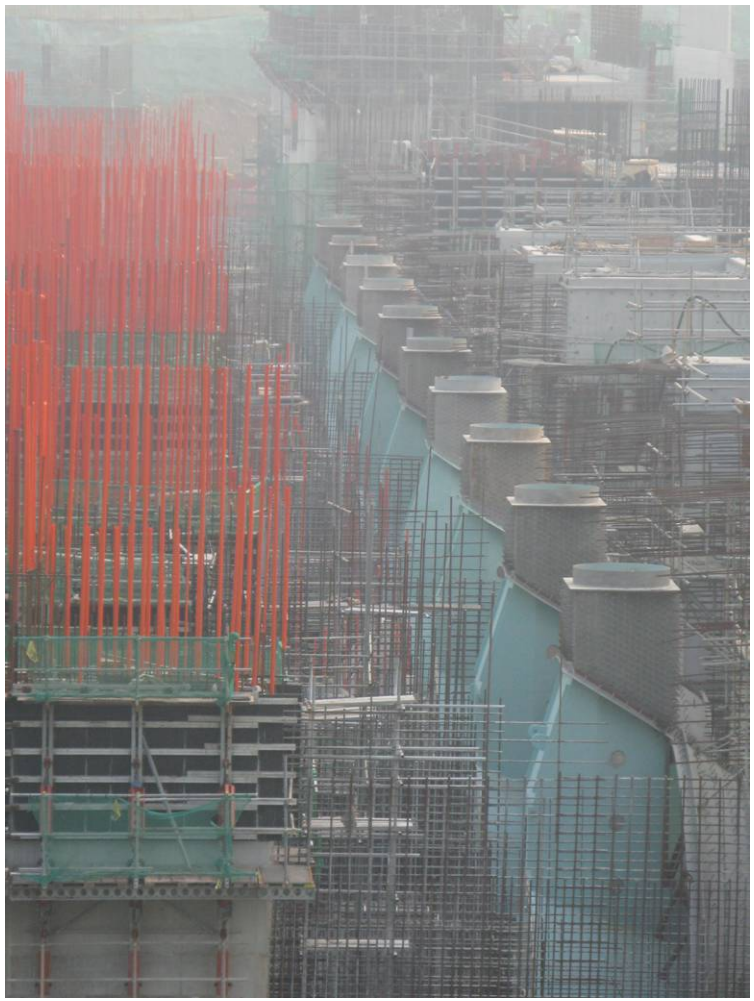
- **Draft tube concreting**

SIHWA TIDAL – Site Installation

- **Powerhouse Concrete Structure**

SIHWA TIDAL – Site Installation

- **Installation of Bulb Casings and Outer Gate Barrel Ring**



SIHWA TIDAL – Site Installation

Concreting of Bulb Casings

SIHWA TIDAL – Site Installation

- **Simultaneous Work on 10 Units**

SIHWA TIDAL - After Completion

SIHWA TIDAL – Tidal Bulb Design